Twentieth-century expansion of floodplain forest in the context of channel transformation of Polish Carpathian rivers

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A considerable increase in forest cover that occurred in the Polish Carpathians over the 20th century (Kozak et al., 2007) reflected not only the increase in the proportion of forest on hillslopes but also on valley floors. In the second half of the 19th century, valleys of Polish Carpathian rivers were typified by a lack or only scarce occurrence of floodplain forest (e.g. Wyżga et al., 2012). This situation was also typical of other mountain areas in Europe (Kondolf et al., 2002; Rinaldi et al., 2013). The lack of floodplain forest in major river valleys in mountain regions resulted from the formation of wide, highly mobile river channels and the use of riparian areas for cultivation and grazing. In the 20th century, there was a significant increase in forest cover of the Polish Carpathians and at the same time, floodplain forest developed in the valleys of major Carpathian rivers. Forest encroached on higher parts of former river channels that were no longer disturbed by channel processes after channelization and/or channel incision resulting from gravel mining. The abandonment of the pastoral and agricultural use of riparian areas, especially in the second half of the 20th century, enabled the expansion of forest also on pre-channelization floodplains.

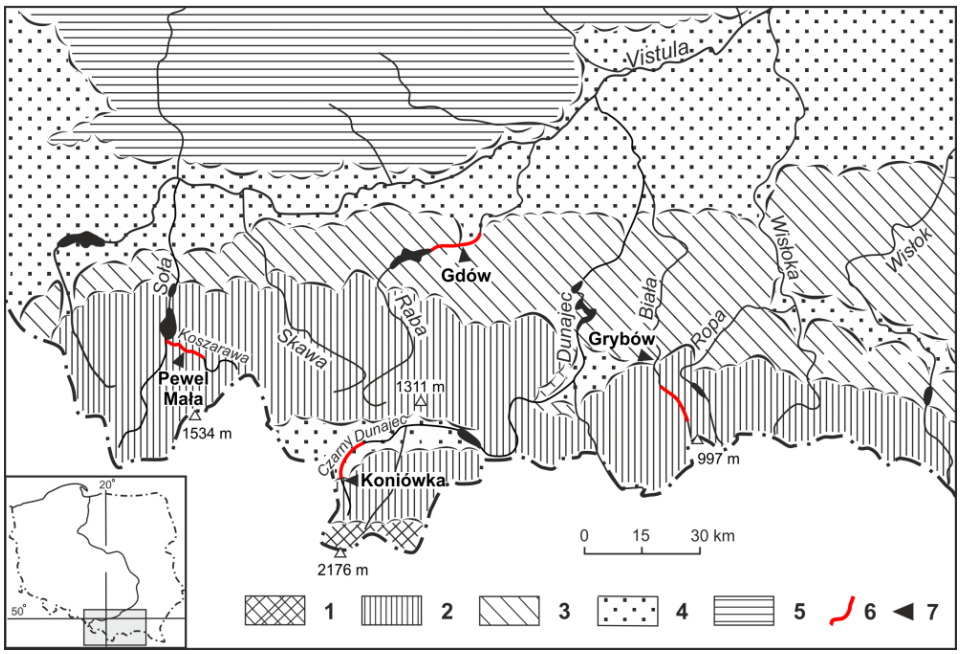

Figure 1 Location of the studied reaches of the Czarny Dunajec, Koszarawa, Biała and Raba rivers shown on the background of physiogeographic regions of southern Poland. 1 – high mountains; 2 – mountains of intermediate and low height; 3 – foothills; 4 – intramontane and foreland basins; 5 – uplands; 6 – analysed river reaches; 7 – water-gauge stations.

The development of floodplain forests in the 20th century is illustrated with the example of reaches of four Carpathian rivers: the middle course of the Czarny Dunajec, lower course of the Koszarawa, the upper course of the Biała and the middle course of the Raba (Fig. 1). The analyses were performed with the use of following cartographic and photogrammetric materials: (i) map of the Third Military Survey of the Austro-Hungary at a scale of 1:25000 from the 1870s, which was scanned and georeferenced in the PL–1992 coordinate system using control points, (ii) orthophotos produced from archival aerial photographs taken at around the mid-20th century at scales varying between 1:10000 and 1:24000 (Czarny Dunajec – 1954, Raba – 1955, Koszarawa – 1958, Biała – 1967) and (iii) orthophotos from 2009 at a scale of 1:10000. The boundaries of floodplain and active zone of the rivers shown on the historical map and the orthophotos were digitized using ArcGIS software. The following land cover categories (geomorphic units) were subsequently distinguished and digitized within the active river zones: low-flow channels, channel bars and islands. In turn, the floodplain areas were subdivided into floodplain forest, unforested area (collectively for meadows and pasture, arable land and wasteland) and built-up area. The width of active river zone, total area and width of river corridor, area of floodplain, low-flow channels, bars, islands, floodplain forest, unforested floodplain area, built-up area, as well as a combined area of floodplain forest and islands in 100-m-long segments were determined. Then, the percentage of individual land cover categories in the total area/width of the river corridor in each segment was calculated and mean proportions of these categories at particular analysed dates were obtained for the study reaches of the four rivers.

All the analysed Polish Carpathian rivers experienced significant narrowing between the second half of the 19th century and the first decade of the present century, but they differed in the timing and the degree of the narrowing. The width of the Czarny Dunajec River decreased in that time by three-fourths and the degree of the river narrowing was similar in both periods analysed (between the 1870s and the mid-20th century, and since then to 2009). The Raba River narrowed by more than three-fourths, with a greater part of the narrowing having occurred in the second period. The narrowing of the Koszarawa took place in the second half of the 20th century, while most of the narrowing of the Biała was recorded in the first half of the century. The Raba experienced the most significant narrowing, by 78%, while the width of the Koszarawa decreased least – by 35%. This narrowing of the rivers was mainly caused by the regulation of their channels, which was reflected in a decrease in the number of low-flow channels and in the proportion of channel bars in the total area of river corridors. As a result of the river narrowing, the proportion of floodplains in the total area of the river corridors increased; in the case of the Biała, it doubled from 42% to 84%. The expansion of the floodplain forests was reflected in a very significant increase in the proportion of forested area on the valley floors – in 2009 forest covered from 28.5% (Czarny Dunajec) to 46.5% (Koszarawa) of the total corridor area. The most significant increase in forest area since the second half of the 19th century was recorded in the Biała valley. In the valleys of the Czarny Dunajec, Biała and Raba rivers, the increase in the area of floodplain forest between the 1870s and 2009 was almost the same as that in floodplain area (Fig. 2). Here, floodplain forest developed on lateral, higher parts of the former, wide channels that were reclaimed from the rivers as a result of river channelization and incision. In the Koszarawa valley, until the mid-20th century floodplain area did not increase but floodplain forest developed at the cost of agriculturally and pastorally used areas. In the second half of the century, lands reclaimed from the river as a result of its channelization were also left for forest development. In the first half of the 20th century, forest development on floodplains of all studied Polish Carpathian rivers was accompanied by the appearance or increased occurrence of islands in the active river zones. However, as channelization works have led to elimination of islands from the rivers,

islands persisted only in the reaches that avoided channelization in the second half of the 20th century.

The 20th-century forest expansion in the valleys of Polish Carpathian rivers must have increased the diversity and complexity of river environmental conditions. The occurrence of forest communities on river banks leads to the increase in the biodiversity of not only riparian ecosystem but also aquatic and terrestrial ecosystems within the active zone of rivers (Gurnell et al., 2005). Recently, a number of Natura 2000 areas have been delimited in river valleys (Perzanowska, Grzegorczyk, 2009) in recognition of the environmental value of forested river corridors, which only 100 years before were devoid of forest (Kondolf et al., 2007). However, the most evident result of the development of floodplain forests is the delivery of considerable amounts of large wood to river channels during floods (Wyżga, 2007). Woody debris is considered beneficial for the functioning of river ecosystems, but it can also generate flood hazard in the vicinity of bridges and in floodplain areas.

The development of forest communities in floodplain areas and within the active zones of mountain rivers considerably influenced the functioning of rivers. This is essential for the improvement of river management practices that should take into account the resultant changes in physical processes in rivers, the beneficial influence of forest communities on the environmental values of river corridors, and the impact of large wood delivered to river channels on flood hazard in the valleys.

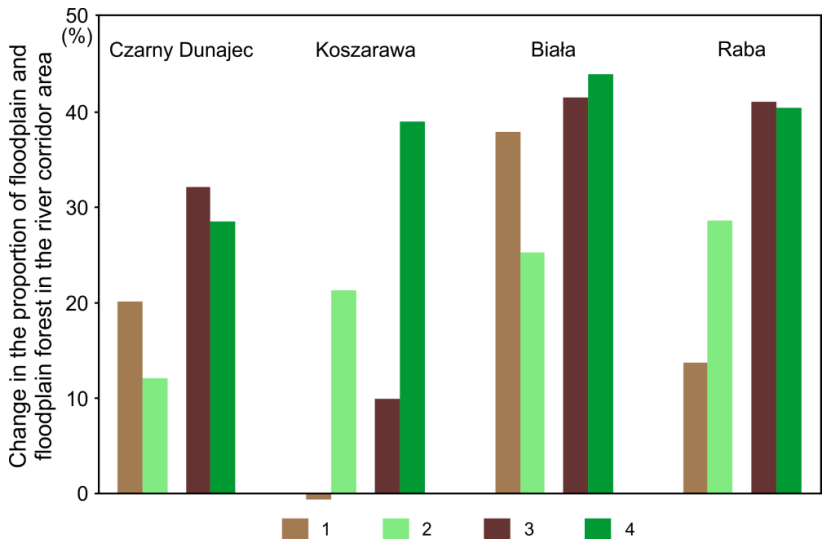

Figure 2 Changes in the average proportion of floodplain (1, 3) and floodplain forest (2, 4) in the total area of the corridor of the Czarny Dunajec, Koszarawa, Biała and Raba rivers between the 1870s and the mid-20th century (1–2) and between the 1870s and 2009 (3–4).

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